

# METHOD AND APPARATUS FOR MECHANICALLY BALANCING THE DISK PACK OF A HARD DISK DRIVE

## BACKGROUND OF THE INVENTION

### 1. Cross Reference to Related Applications

5        This application claims the benefit of the priority date of United States provisional patent application serial number 60/413,734, filed September 25, 2002, the specification of which is hereby incorporated in its entirety.

### 2. Field of the Invention

10        The present invention relates to mechanically balancing the disk pack in a hard disk drive.

### 3. Background Information

15        Hard disk drives contain a plurality of magnetic heads coupled to rotating disks. The disk pack rotates the disk surfaces in a hard disk drive. Imbalances in the disk pack adversely affect communication to and from the rotating disk surfaces. Therefore, disk packs must be balanced to minimize rotational variation at the disk surfaces.

20        The typical prior art disk pack includes a spindle motor, one or more disks, possibly one or more spacers, and a disk clamp. Bolts or screws couple the disk clamp to the spindle motor, acting to clamp the disk(s) and spacers into a rigidly coupled assembly which is rotated by the spindle motor during operation.

Making disk packs includes a rotational balancing process, which mechanically aligns the disk packs by attaching counterbalances. A typical balance tolerance for a disk pack is a variation in angular momentum of 35 milligram-centimeters, as measured by a balance calibration system.

5        There are several existing approaches to balancing disk packs based upon different counterbalances. These existing approaches have created problems, which have added to the cost of production and/or diminished the reliability of the produced hard disk drives.

A first prior art balancing approach involves altering a symmetric ring coupled to a disk clamp. Cutting, drilling, or punching are used to alter the ring.

10        A second approach involves drilling one or more holes in either the disk clamp or the spindle motor hub. The spindle motor hub is a spindle motor region containing the screw holes used to couple with the disk clamp when making the disk pack. Machining holes in the disk clamp or the spindle motor hub may introduce contaminants such as machine tailings and machine oils. Furthermore, the machining required is specific to the particular disk pack and  
15 must meet narrow tolerances, making this approach expensive.

A third approach involves injecting glue and/or heat sealing plastic at selected spots, and in selected amounts, near the disk clamp to counterbalance the disk pack. This injection releases contaminants, which require cleaning procedures to restore the cleanliness of the disk system when assembled. The injected compounds also require a specific environment in order to harden  
20 correctly, further adding cost, and often delays, until the hardening process is completed.

Accordingly, what is needed are counterbalances, and methods of balancing disk packs using such counter balances, which do not require unit specific machining and which do not create contamination problems.

## BRIEF SUMMARY OF THE INVENTION

The present invention includes methods of making a balanced disk pack from a disk pack that may have previously been unbalanced. The invention also includes the balanced disk packs resulting from balancing the disk packs, as well as the hard disk drives built with such balanced  
5 disk packs. The invention further includes the apparatus making a balanced disk pack from a disk pack.

The disk pack typically includes a spindle motor rigidly coupled with a disk clamp, and aligned by at least two open screw holes. The disk pack balancing methods use no unit-specific machining operations. Using cleaned counterbalances minimizes contamination, which may  
10 eliminate the cost and production delays of glues and injected plastics.

The invention includes at least one mechanical counterbalance for balancing a disk pack. The mechanical counterbalance fits into an open screw hole, and locks against a locking plate collection member. The locking plate collection typically includes the disk clamp and the spindle motor.

15 The disk clamp may be the preferred locking plate collection member, because if the disk pack with locked mechanical counterbalances fails to balance, disassembling can salvage at least the spindle motor and disks.

Preferred mechanical counterbalances include a cylindrical shaft rigidly coupled to a latching assembly and a balance weight. The cylindrical shaft centers around a primary axis. The  
20 latching assembly includes a compressible latch rigidly coupled to a latch gap zone. The balance head rigidly couples to the latch gap zone. The latching assembly, including the compressible latch, and the latch gap zone, center around the primary axis.

The invention includes selecting a counterbalance from a counterbalance type collection of at least two counterbalances with total masses, which are different or distinct. Such  
25 counterbalances will be referred to as distinct total masses.

## BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages, may best be understood  
5 by reference to the following description, taken in connection with the accompanying drawings, in which:

Figure 1 shows an exploded schematic view of a balanced disk pack in a hard disk drive;

Figure 2 shows a side cross-sectional view of the disk pack in the hard disk drive of  
Figure 1;

10 Figure 3 shows a perspective view of the disk pack of Figures 1 and 2;

Figure 4 shows a more detailed view of the cross-section of Figure 2;

Figure 5A shows a top cross-sectional view of a mechanical counterbalance of Figures 1  
to 4;

15 Figure 5B shows a perspective view of the mechanical counterbalance of Figures 1 to 5A;

Figure 5C shows a side view of the mechanical counterbalance of Figures 1 to 5B;

Figure 5D shows the view along a cut line of the fins of Figure 5C;

Figure 6A shows a top cross-sectional view of a second preferred mechanical  
counterbalance which could be used in Figures 1-4;

20 Figure 6B shows a side view of the second mechanical counterbalance of Figure 6A;

Figure 6C shows a side cross-sectional view of the second mechanical counterbalance of  
Figures 6A-6B;

Figure 7 shows an apparatus for making a balanced disk pack from a disk pack;

Figure 8 shows a preferred apparatus for making the balanced disk pack as in Figure 7;

25 Figure 9A shows a detail of the program system of Figure 8;

Figure 9B shows a detail performing the balance operation for the open screw hole of  
Figure 9A;

Figure 10A shows a detail selecting a mechanical counterbalance for the open screw hole  
of Figure 9B;

Figure 10B shows a detail of inserting the selected counterbalance into the open screw hole until the mechanical counterbalance locks into the open screw hole of Figure 9B;

Figure 11A shows a detail of selecting the mechanical counterbalance for the open screw hole of Figure 9B;

5        Figure 11B shows a detail of inserting the selected counterbalance into the open screw hole of Figure 9B;

Figure 12A shows of locking the selected counterbalance into the open screw hole of Figure 11B;

Figure 12B shows further making the balanced disk pack of Figures 8 and 9A;

10       Figure 13A shows further locking the mechanical counterbalance into the open screw hole of Figure 11B;

Figure 13B shows further analyzing the disk pack for the balancing operation for the open screw hole of Figure 9B.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description is provided to enable any person skilled in the art to make and use the invention and sets forth the best modes presently contemplated by the inventors for carrying out the invention. Various modifications, however, will remain readily apparent to those skilled in the art, since the generic principles of the present invention have been defined herein.

The invention includes using at least one mechanical counterbalance 100 for balancing a disk pack of a hard disk drive as shown in Figures 1 to 4. Figures 1 to 4 show a disk pack. A disk pack includes a spindle motor 80 and at least one disk 12 rigidly coupled with the disk clamp 82.

The disk pack is aligned by at least two open screw holes 85-A and 85-B. Disk packs may further include disk spacers 84. Open screw holes 85-A and 85-B are shown only in Figure 4.

Figure 1 shows an exploded schematic view of a hard disk drive 10, including a balanced disk pack employing a preferred mechanical counterbalance 100. The hard disk drive 10 also includes the following. A hard disk drive base plate 90, a hard disk drive base 92, a second disk 14, separated by a disk spacer 84, a voice coil actuator 30, and the hard disk drive cover 94.

Figure 2 shows a side cross-sectional view of hard disk drive 10 with the mechanical counterbalance 100 of Figure 1 inserted into open screw hole 85-C of the disk pack, at least partially creating the balanced disk pack.

Figure 3 shows a perspective view of the balanced disk pack of Figures 1 and 2. Two mechanical counterbalances 100-A and 100-B are inserted into two open screw holes in disk clamp 82. The Figure also includes a disk ring 86, disk spacer 84, and disk 12.

Figure 4 shows a magnified view of a portion of the cross-section of Figure 2. The mechanical counterbalance 100 is shown locking against the disk clamp 82. When fitted into the open screw hole 85-C, the mechanical counterbalance 100 aligns with both the disk clamp 82 and the spindle motor 80.

The mechanical counterbalance 100, in Figures 2 and 4, includes means for fitting into the open screw hole, and locking against a locking plate collection member.

The locking plate collection of Figures 1 to 4 includes the disk clamp 82 and the spindle motor 84. The locking plate collection may also include the disk spacer 84 coupled between the disk clamp 82 and the spindle motor 80.

Typically, disk spacers do not include screw holes, thus the disk spacers 84, of Figures 1 to 4, may or may not include screw holes. In hard disk drives possessing more than one disk, the disk pack further includes one or more additional disk spacers 84, as seen in Figure 1. A disk pack may also include disk spacer 84 in hard disk drives using just one disk 12, as in Figures 2, 3 and 4.

Figures 5A to 6C show various embodiments of the mechanical counterbalances 100 of Figures 1 to 4.

The mechanical counterbalance 100 in Figures 5A to 5C includes a compressible latch 130 as a compressible ridge ring. Figures 5A, 5B and 5C show a top cross-sectional view, a perspective view, and a side view of the mechanical counterbalance 100 of Figures 1 to 4.

The mechanical counterbalances 100 of Figures 5A to 6C include a cylindrical shaft 120 rigidly coupled to a latching assembly 130 to 140 and a balance weight 110. The cylindrical shaft 120 is centered around a primary axis 122. The latching assembly 130 to 140 is also centered around primary axis 122. The latching assembly 130 to 140 includes a compressible latch 130 rigidly coupled to latch gap zone 140. The balance head 110 rigidly couples to the latch gap zone 140.

The compressible latch 130 in Figures 5D to 6C is a ring of three compressible fins. Figure 5D shows the view along cut line 102, of Figure 5C, for the fins 132, 134, and 136. Figure 6A, 6B and 6C show top cross-sectional, side, and side cross-sectional views of a preferred mechanical counterbalance 100. The compressible latch 130 may include two or more fins.

The mechanical counterbalance 100 of Figures 5A to 6C may be primarily composed of one material formed into the cylindrical shaft 120, the latching assembly 130 to 140 and the balance weight 110. The material may essentially be a castable material, such as plastic. The plastic may preferably be a version of nylon. In alternate embodiments, the counterbalance 100 maybe formed of several different materials.

The mechanical counterbalance 100 may preferably be free of contaminants. Example contaminants include a particle larger than a first specification, a hanging burr larger than a second specification, and a contaminant determined by a third specification. Each of these specifications is derived from a reliability specification used in the manufacturing of the hard disk drive.



The balance weight 110 of Figures 5A to 6C includes an interior face 112, exterior face 114, and side faces 116 and 118.

Mechanical counterbalance 100 has a total mass at essentially the primary axis 122 (Figures 5A, 5B, 6A, and 6B) when balancing the disk pack. Mechanical counterbalance 100 preferably balances the disk pack by fitting the primary axis 122 through the center of the open screw hole 85-C.

As in Figures 2 and 3, the following occurs when inserting the mechanical counterbalance 100 of Figures 5A to 6C into an open screw hole of the disk pack. The cylindrical shaft 120 fits into the open screw hole. The compressible latch compresses while passing through the screw hole, and expands after passing through the screw hole to lock the mechanical counterbalance 100 against a locking plate collection member.

Figures 5A-6C also show the following. The means 120 for fitting mechanical counterbalance 100 into at least one open screw hole 85. The means for locking mechanical counterbalance 100 into the open screw hole against a locking plate collection member, after fitting mechanical counterbalance 100 into the open screw hole 85. The means for locking includes the compressible latch 130, the latch gap zone 140, and the balance head 110.

Figures 7 and 8 show two embodiments supporting the invention's balancing method for disk packs.

The invention includes a method of balancing a disk pack involving selecting a mechanical counterbalance from a counterbalance type collection. The counterbalance type collection comprises at least two counterbalances, each with a distinct total mass. In experiments by the inventors, two counterbalances had total, preferred masses of about 24 mg and 54 mg.

Figure 7 shows an apparatus for making a balanced disk pack 420 from a disk pack 410. The disk pack 410 includes a spindle motor 80 rigidly coupled with a disk clamp 82. The spindle motor 80 aligns with the disk clamp 82 by at least two, and preferably four, open screw holes 85-A to 85-D.

Figure 8 shows a preferred apparatus for making a balanced disk pack 420 from a disk pack 410 as in Figure 7. The method uses an assembly workstation 400 controlled by a computer executing a program system 530 of program steps residing in memory 520.



The mechanical counterbalance mass collection 450 includes at least two members 460 and 462. The mechanical counterbalance mass collection members are the distinct total masses of the types 480 and 482 of the mechanical counterbalance type collection, as in Figures 7 and 8.

As shown in Figure 7, arrows 324 and 422 preferably represent means for inserting the selected counterbalance 102 into the screw hole.

Discussion of making balanced disk packs hereafter will be in terms of the flowcharts of program system 530 of Figure 8. This simplifies the discussion, and is not meant to limit the scope of the claims. Figures 9A to 13B show the method of balancing a disk pack, using the invention's mechanical counterbalance.

The following flowcharts of the methods of the invention possess arrows with reference numbers. These arrows signify flow of control, and sometimes data. The arrows support implementations including at least one program step, or program thread, executing upon a computer, inferential links in an inferential engine, state transitions in a finite state machine, or learned responses within a neural network.

The operation of starting a flowchart refers to at least one of the following. Starting may refer to entering a subroutine in a macro instruction sequence in a computer. Starting may refer to entering into a deeper node of an inferential graph. Starting may refer to directing a state transition in a finite state machine, possibly while pushing a return state. Starting may refer to triggering a collection of neurons in a neural network.

The operation of termination in a flowchart refers to the completion of operations. It may result in a subroutine return, traversal to a higher node in an inferential graph, popping of a previously stored state in a finite state machine, and/or return to dormancy of firing neurons in a neural network.

A computer as used herein will include, but is not limited to, an instruction processor. The instruction processor includes at least one instruction processing element and at least one data processing element, each data processing element controlled by at least one of the instruction processing elements.

Figure 9A shows a program system 530 of Figure 8 for making the balanced disk pack 420 from the disk pack 410, for each of the open screw holes 85. Operation 1002 analyzes the disk pack 410 for a balancing operation for the open screw hole. Operation 1012 performs the balance operation for the open screw hole.

Figure 9B shows a detail of operation 1012 of Figure 9A, if a balance action is determined for the open screw hole. Operation 1032 selects a mechanical counterbalance for the open screw hole to create a selected counterbalance 102 of a total mass. Operation 1042 inserts the selected counterbalance 102 into the open screw hole, until the selected counterbalance locks  
5 into the open screw hole, at least partially creating the balanced disk pack.

Figures 10A and 10B show one of several possible, equivalent implementations of the operations of Figure 9B, including implementations with a shared test.

Figure 10A shows a detail of operation 1032 of Figure 9B. Operation 1132 determines if a balance action is needed for the open screw hole. When the determination 1134 is Yes,  
10 operation 1136 selects a mechanical counterbalance for the open screw hole to create a selected counterbalance 102 of a total mass.

Figure 10B shows a detail of operation 1042 of Figure 9B. Operation 1152 determines whether the open screw hole needs a balance action. When the determination 1154 is Yes, operation 1156 inserts the selected counterbalance 102 into the open screw hole until the  
15 selected counterbalance 102 locks into the open screw hole at least partially creating the balanced disk pack.

Figure 11A shows a detail of operation 1032 of Figure 9B. Operation 1172 selects the mechanical counterbalance for the open screw hole from the counterbalance collection 470 and from the counterbalance mass collection 450, creating the selected counterbalance 102 with the  
20 total mass, as shown in Figures 8 and 9.

In Figures 7 to 11A, the selected counterbalance 102 is an instance of a member of the mechanical counterbalance collection 470.

The arrows in Figures 7 and 8 pointing to and pointing from the selected counterbalance 102 preferably represent assembly feed mechanisms.

Figure 11B shows a detail of operation 1042 of Figure 9B. Operation 1192 fits the  
25 selected counterbalance 102 into the open screw hole. Operation 1202 locks the selected counterbalance 102 into the open screw hole against a locking plate collection member, after fitting the selected counterbalance into the open screw hole.

Figure 12A shows a detail of operation 1202 of Figure 11B. Operation 1202 locks the  
30 selected counterbalance 102 into the open screw hole against the disk clamp after fitting the selected counterbalance into the open screw hole.

Figure 12B shows a detail of program system 530 of Figures 8 and 9A providing, if the disk pack fails to balance, disassembly of the disk pack with fitted counterbalances to salvage at least the spindle motor and the disks. This is performed as follows. Operation 1242 confirms a balance failure for the disk pack. Operation 1252 removes the disk clamp, and all of the  
5 mechanical counterbalances locked to the disk clamp, from the disk pack to create a partial disk pack. Operation 1262 then rigidly couples a second disk clamp to the spindle motor of the partial disk pack, and aligns it by open screw holes, to recreate the disk pack.

Figure 13A shows a detail of operation 1202 of Figure 11B. Operation 1302 compresses a compressible latch into the open screw hole. Operation 1312 expands this latch after  
10 compressing it into the open screw hole to lock the mechanical counterbalance against the locking plate collection member.

Figure 13B shows a detail of operation 1002 of Figure 9B. Operation 1352 uses a disk pack balance instrument 304 of Figure 8 to analyze the disk pack 410 for the balancing operation. Hoffman manufactures the preferred disk pack balance instruments.

15 Those skilled in the art will appreciate that various adaptations and modifications of the just-described preferred embodiments can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.